REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-09-0014

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
10//2008	ANNUAL and FINAL	15 June 2006 to 14 Aug. 2008

4. CONGRESSIONAL EAR-MARK FY 08
(CONGRESSIONAL EAR-MARK FY 08)BIO/NANO ELECTRONIC DEVICES AND SENSORS

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-06-1-0467

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
KINZY JONES
ADVANCED MATERIALS ENGINEERING RESEARCH INSTITUTE
FLORIDA INTERNATIONAL UNIVERSITY

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
FLORIDA INTERNATIONAL UNIVWERSITY
OFFICE OF SPONSORED RESEARCH
11200 SW 8TH STREET- MARC 430
MIAMI, FL 33199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AF OFFICE OF SCIENTIFIC /NE
875 NORTH RANDOLPH STREET
Arlington VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION A: APPROVED FOR PUBLIC RELEASE

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This effort consists of five research thrusts: (1)
Dense Memory Devices-(1)3-D magnetic recording was enhanced using patterned soft underlayers and interlayer, (2) Cold cathode microwave generator and ceramic electron multiplier-ceramic multiplier using a novel secondary electron yield materials of MgO and CNT was demonstrated as well as cooling structures based on capillary cooling.(3) CNT-based Bio-nano Sensors-ingle walled CNT structures with FIB generated nanogaps have been used to probe single DNA strands, using DNA strands from known pathogens (4) Silicon/polymer nanophotonics- silicon based nano-slot waveguide device was fabricated, as well as micro ring resonators. Flexible micromanipulator probes developed for probing waveguides. (5) Doped nano-diamonds and nanoceramic lasers- optically transparent YAG were demonstrated, and yttrium aluminum perovskite (YAP) were developed of high thermoluminescence efficiency

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Kinzy Jones
					19b. TELEPHONE NUMBER (include area code) 305-348-2345

20090312182

TO: TECHNICLAREPORTS@AFOSR.AF.MIL
HAROLD.WEINSTOCK@AFOSR.AF.MIL

SUBJECT: ANNUAL PROGRESS STATEMENT TO Dr. Harold Weinstock, Program Director, AFOSR

GRANT: BIO/NANO ELECTRONIC DEVICES AND SENSORS

Grant #: FA-9550-06-1-0467
Reporting Period: May 1, 2006- Aug. 14, 2008

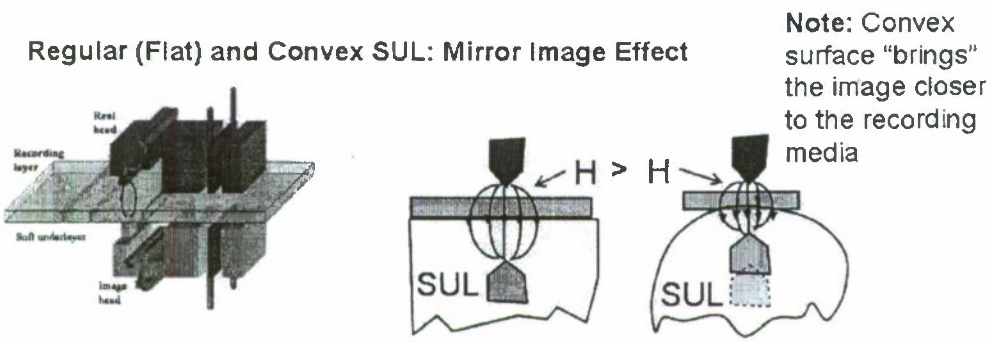
Principle Investigator: W. Kinzy Jones
Professor and Director, Advanced Materials Engineering Research Institute
Florida International University
Miami, FL 33199
305-348-2345; jones@fiu.edu

Final Report Accomplishments 06/08

A. Dense Memory Devices (Khizroev)

The key objectives of the proposal are: 1) understanding of the physics underlying the proposed concept of three-dimensional (3-D) magnetic recording and memory, 2) development of various mechanisms to record and read data in a 3-D magnetic system, 3) development of experimental methods to study properties of a 3-D magnetic system, 4) dissemination of the accomplishments through filing patents, publishing refereed papers and presenting at international conferences and meetings in the field, and 5) promotion of the proposed technology via the increased interactions with the industry and involvement of researchers in other institutions.

Throughout this effort, a new concept of patterned soft underlayer (PSUL) and interlayers (PSUI) was introduced. A patent was filed two years ago [i]. The concept was described in detail during the last year progress report. The schematics in Figure 16 illustrate the concept of bringing the image of a recording head closer to the recording media if a convex soft underlayer is used. Using a PSUL is equivalent to using a periodic array of images. In this case, each image effectively generates its own field. If the presence and arrangement of images could be controlled, this concept could be used to control the recording and sensitivity fields (used for recording and reading information, respectively) across 3D recording media. To summarize, the key advantages are:



- PSUL increases the recording field across the thickness by at least a factor of two. PSUIs further increase the number of accessible layers across the thickness by at least a factor of three.

- PSUL and PSUI increase the recording field gradient across the thickness of a 3D recording media thus promoting ultra-high density recording

B. High Power Cold Cathodes for Microwave Generators (Choi et al)

We have designed a high secondary electron yield (SEY) microchannel plate (MCP) for high current applications. The channel parameters i.e. aspect ratio, tilt and effect of high SEY materials were determined utilizing example 3D 80/81 of charged particle optics (CPO-3D/2D) module. From figure 1a it can be observed that high gain can be achieved either with a channel of aspect ratio ~ 40 or with a tilt of 5°-15°, however fabrication and coating of such channels is relatively laborious. Thus the most feasible method to achieve high gain from an MCP is by utilizing a high SEY material inside the channel as shown by simulation results in figure1b.

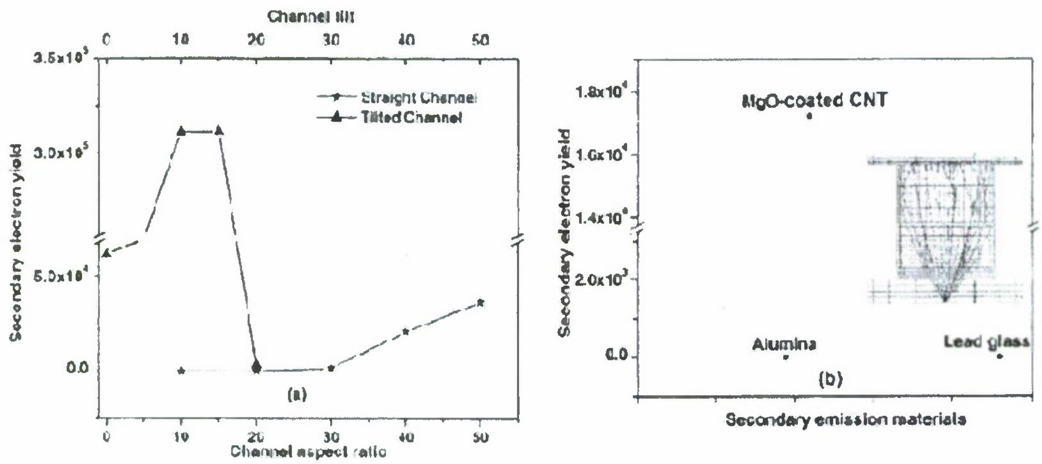


Figure 1. Simulation results
applied voltage: 1000V, mat
observed for MgO-coated ch

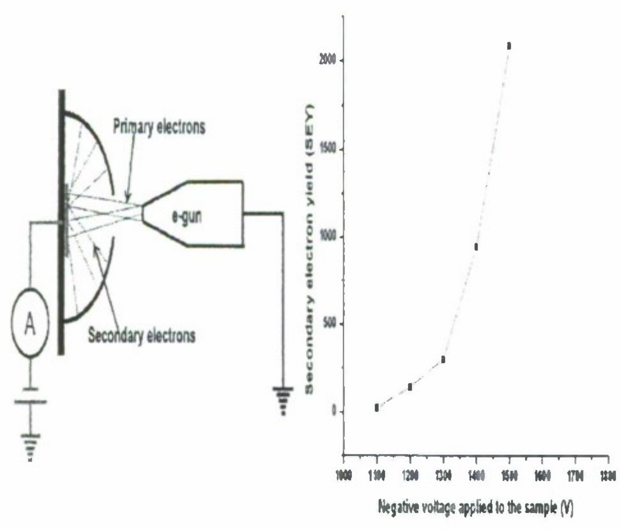


Figure 2. (a) Schematic of secondary electron measurement setup (b) representative SEY plot of nano-material consisting of magnesium oxide (MgO)

is shown
current fi

surrounding the sample; in addition the specimen current was also measured. The SEY was calculated as a ratio of secondary to primary current (i_s/i_p) and also from the following equation (1- i_{sample}/i_p). The measured SEY of this material was as high as 10^4-10^5. This was limited due to the current limitation of our measuring electronics which can measure only 5 mA.

Based on the simulation and S[redacted]esults a novel high yield ceramic (Al_2O_3) M[redacted]as been fabricated. The MCP was based on our high SEY nano-material consisting of magnesium oxide (MgO) and carbon nanotubes (CNT). An enhancement of ~18-25 times in the field emission current has been observed, when the MCP was placed above CNT field emitter cathode. The schematic of the test structure is shown in figure 3a. For the cathode part a novel multistage CNT emitter structure consisting of thin-MWNT/SWNT on MWNT has also been demonstrated. This structure showed improved field emission and higher field emission current due to enhanced electric field concentration at the emitter tip. Array of this structures were synthesized on porous silicon.

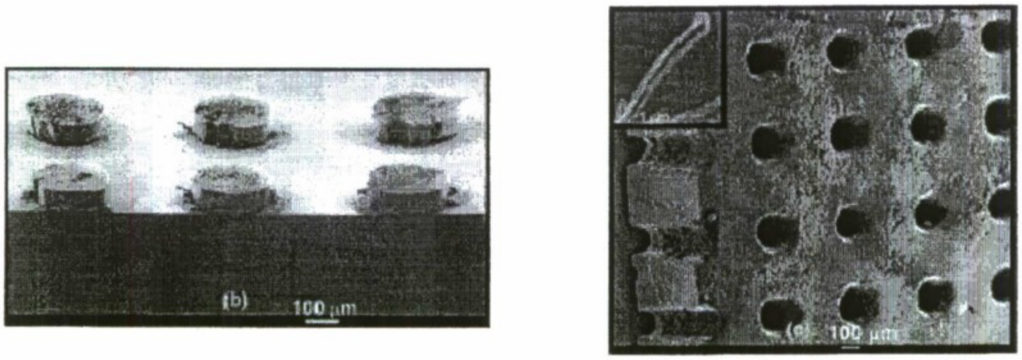
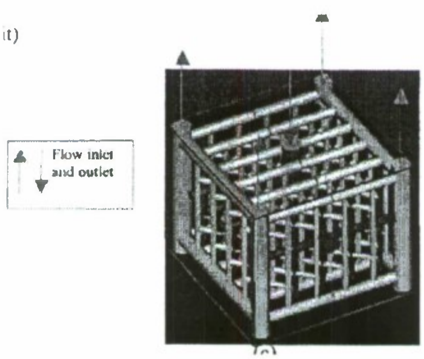


Figure 3(a) multistage CNT array and (b) ceramic (Al_2O_3) MCP with nano-structured MgO-coated channel as secondary emissive layer

Advanced cooling of the electron multiplier was also evaluated. The development of a micro network piping arrangement provides a ultra-high performance micro heat sink where the 3-D network piping geometry provides a very high surface/volume ratio, capable of reaching 10^5 W/cm^3 theoretical cooling performance, an order of magnitude higher cooling capacity than current microchannel heat sink. Capillary heat sinks lends itself to the cooling of a ceramic electron multiplier since the multiplier channels run only vertically and the cooling structure can be integrated between the multiplier channels. Additionally, because of the high cooling capacity, they can also be used to cool the anode structure. Additionally, the capillary diameter can be modified to account for the increase in thermal load down the channel based on the increased electron multiplication.

Figure 4 shows the conceptual design of the network piping system for a single cooling unit. It consists of a network of tubes that are designed based on the Murray's Law, which states that, for a system of tubes containing a Newtonian fluid in laminar flow, the minimum volume for a given pressure drop occurs when the radii of the tubes at a branch point satisfy the relationship:

$$r_0^3 = r_1^3 + r_2^3 + r_3^3 + ... + r_n^3$$



where r_0 is the radius of the incoming tube, and r_1 , r_2, etc, are the radii of the outgoing tubes. This piping system finds its similarity to a biological circulatory system that links large arteries and veins via smaller vessels ultimately linked by capillary beds. A design has been developed that optimizes the pipe diameter based on 85µm vertical channels and methods of developing a 3-D channel system using this minimum vertical channel have been evaluated. The grid spacing between the vertical channels is variable to

Figure 4- Schematic representation of Capillary Cooler

allow for optimized electron multiplier channels per vertical footprint and the design allows variations in channel diameter in the vertical direction to account for increased thermal loads in the vertical direction of the electron multiplier.

C. Modeling, Design and Synthesis of CNT-based Bio-Nano Sensors (Choi et al)

Objectives:

- Fabrication of CNT nanoelectrodes for DNA detection at single molecular level
- Investigation on the performance of nanoelectrodes at various environmental conditions
- Rapid detection of sequence variation using CNT nanoelectrodes
- Development of highly sensitive CNT probes for electrochemical detection of neurotransmitter at trace concentrations

Accomplishments/New findings:

1. *Fabrication of CNT nanoelectrodes for DNA detection at single molecular level*

In the pursuit to develop novel sensing approaches for rapid detection of biological entities such as pathogen we have been developing single walled carbon nanotube (SWNT) based nanoelectrodes. These nanoelectrodes with their nanoscale dimensions and unique electronic properties have the capability to rapidly and economically detect various analytes at very low concentrations down to few or even single molecules. Single molecule detection of DNA is essential for a wide range of applications which include rapid gene sequencing, drug detection, identification of suspected anthrax and similar strains for biosecurity applications.

The sensor platform consists of nanoelectrodes fabricated by forming a nanogap in individual SWNT. The size of the nanogaps is equal to the length of a single probe DNA (typically ~30 nm). The sensing mechanism is based on obtaining a reproducible current signal when a probe DNA attached between the nanoelectrodes hybridizes with its target complementary strand. We have successfully tested the sensor platform for detecting the DNA fraction of avian *Influenza A* virus (AIV), which is highly pathogenic *and Pseudomonas aeruginosa,* which typically infects the pulmonary tract, urinary tract, burns, wounds, and also causes other blood infections. AA current signal of around 30 pA current (at 1 V) was measured for the dsDNA molecule covalently attached to the SWNT electrode.

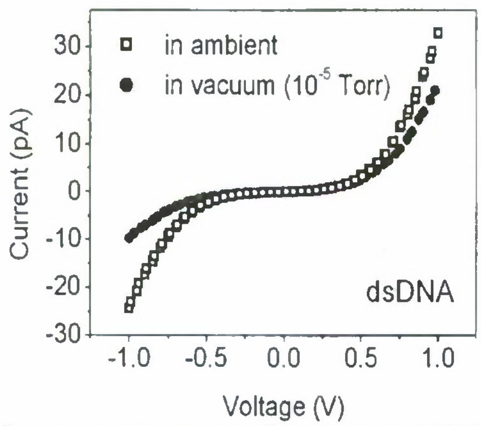


Figure 5. Current flow at room temperature through single dsDNA molecule of 80 base pair length attached between SWNT nanoelectrodes, in ambient and in vacuum conditions.

2. *Investigation on the performance of nanoelectrodes at various environmental conditions*

It has been known that due to the highly dynamic nature of the DNA molecules, their structure and material properties are strongly influenced by local environment thus affecting its electronic properties. We are investigating the influence of perturbations in the local environment such as ionic concentration, pH, counter-ion variation and temperature on the performance of our SWNT nanoelectrode DNA sensor platform. Our results show that the current signal was not affected significantly for slight variation in salt concentrations and pH.

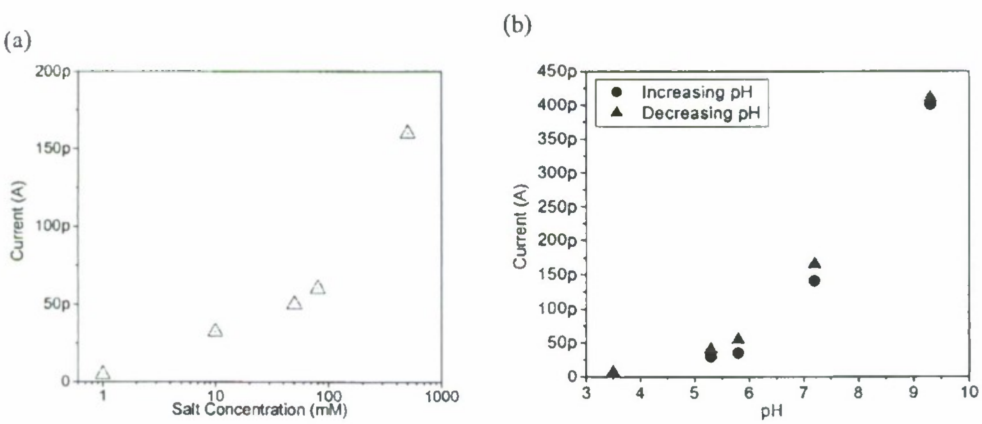


Figure 6. Effect of ionic strength (NaAc) variation on DNA conductivity measured at 1 V bias. At very low ionic strength (<1 mM), the signal diminished; (d)Effect of pH variation on the conductivity of DNA measured at 1 V bias. *I–V* characteristics of the same device washed with buffer solution of different pH values are shown for both a gradual increase and a decrease in pH.

3. *Rapid detection of sequence variation using CNT nanoelectrodes*

We are currently working on detecting unique electronic signatures for different sequences which are required for diagnosis of diseases. Pathogens responsible for disease states, bacteria and viruses, are also detectable via their unique nucleic acid sequences. We are in the process of developing large array of these nanoelectrodes for simultaneous detection of multiple sequences.

D. Silicon/Polymer Nanophotoni[illegible]Panepucci et al)

a. Nanoparticle-Resonator Integration: Develop separation methods of nanoparticles using microfluidic methods.(Jun, McGoron and Panepucci). One of our team members (Dr. S. Jun) moved from FIU. We have since moved to an experimental investigation of the microfluidic separation of compounds in microchannels. Work was carried out with Prof. Bruce McCord from chemistry. A paper was submitted to the journal ***Lab-on-a-Chip.***

b. Simulation of Nanophotonics: Develop silicon-based slot-waveguide devices (Panepucci):

(i) A nanotaper design for coupling into horizontal slot-waveguides was investigated and found to be the best approach when compared to optimized regular nanotapers leading to regular rectangular waveguides followed by butt-coupling into h-slot structures. This result was presented at SPIE Optics&Photonics 2007.

(ii) A method for numerically estimating the Q-factor of photonic crystal cavities was developed and evaluated by comparing with published 3D FDTD models of identical structures and good agreement was found. This result was presented at SPIE Optics&Photonics 2007.

(iii) Silicon tunable micro-ring resonators were investigated for application to communications using wavelength division multiplexing. The device was simulated using multiphysics effects for thermal tuning of the resonance. Detailed experiments were carried out and showed excellent agreement with the proposed simulation model. Total of three papers were published; two in IEEE Photonics Tech. Letters., and one in Optical Engineering. Several conference presentations also resulted from this work as seen below.

(iv) Nano-slot waveguides were investigated as sensors when suspended, forming nano-opto-electromechanical systems, NOEMS. This work showed that the all-optical forces can drive the NOEMS device and that transduction of signals would lead to sensing mechanisms. This work was presented at CLEO 2007, Frontiers in Optics 2006, and IMAPS 2006.

c. Quantum Dot Laser: Study QD integration (Panepucci, McGoron);

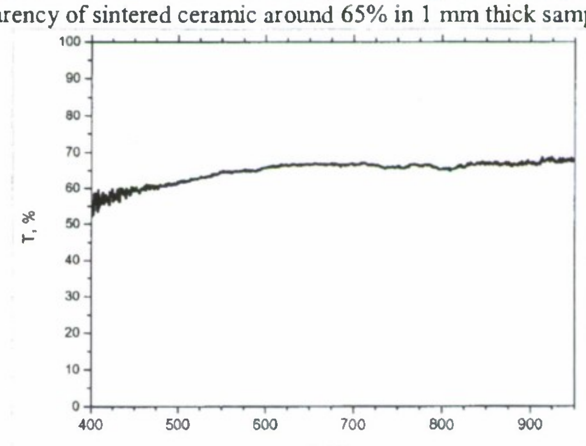
(i) Horizontal silicon slot-waveguide photonic crystal waveguides were investigated and conditions for waveguide propagation were developed. This opens the possibility for high on-chip gain if suitable Quantum Dot doping material is found to fill the slot on this structure. A paper was published in *Optics Express* in 2007.

(ii) Flexible polymer probes were developed for probing our polymer waveguides on-chip. This is important as it should avoid several yield limiting steps and increase throughput in testing. This result was published in *Optics Express* in 2007, and presented as invited paper at IPNRA2008, SPIE Optics&Photonics 2007, as well as presented at CLEO2008.

E. *Doped Nanodiamonds and Microchip Nanoceramic Lasers for Future Devices (Saxena)*

Most of our work was concentrated on technology of optically transparent laser materials. Main problem we are facing is residual porosity after sintering and scattering related to it.

We have obtained optically transparent laser YAG ceramic using high temperature vacuum sintering. Significant progress in improving of optical quality was achieved by adding graphite in hot zone of vacuum furnace during the sintering and crating highly reducing environment. We have reached level of transparency of sintered ceramic around 65% in 1 mm thick samples.



Materials for thermoluminescent dosimetry.

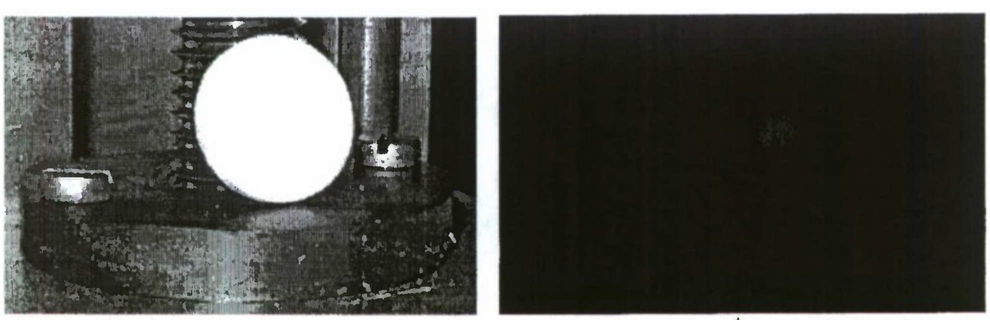
Manganese-doped yttrium aluminum perovskite (YAP) single crystals became of interest after it was showed their high potential for holographic recording and optical data storage applications. Later, a high thermoluminescence efficiency of the crystals was shown, which can be used for thermoluminescent dosimetry of ionizing radiation. From the technological point of view, polycrystalline materials offer significant advantage over single crystals due to the ease and the cost of fabrication. This prompts us to obtain and study Mn-doped YAP ceramics.

A number of polycrystalline samples of Mn-doped YAP with different Mn concentrations and different Y_2O_3–Al_2O_3 compositions were prepared by solid-state reaction starting from nanocrystalline oxides. The sintering temperature of 1620–1630 K was experimentally chosen as optimal for obtaining YAP ceramics of highest phase purity in the experimental conditions used. Traces of the YAM phase were observed for the samples obtained at lower temperature, whereas traces of the YAG phase dominate at higher temperature. Scanning electron microscopy of the obtained ceramics samples showed that the grains dimensions ranged from 0.3 to 0.7 μm.

The optical spectroscopy studies testify that different ways of doping (at the expense of yttrium or aluminum) in our sintering conditions do not affect the character of Mn ion incorporation into the YAP structure. In all cases manganese is present in the form of Mn^{4+} ions occupying Al positions and shows the same emission intensity at a certain nominal doping level. The deviation from the YAP stoichiometry caused by the manganese doping, in particular for the $Y_{1-x}Mn_xAlO_3$ series, leads to parasitic YAG phase formation. The obtained YAP:Mn ceramics demonstrate a high sensitivity to UV or visible light. The samples after exposure show characteristic thermal glow during heating above room temperature. The TL emission occurs in the red spectral region around 710 nm and corresponds to luminescence of Mn^{4+} ions.

The first TL peak situated slightly above room temperature causes a considerable thermal glow of the exposed sample slightly heated above room temperature. Because of this effect the studied ceramics can be successfully used as a TL screen for visualization of local heating of various origins, e.g. a heating caused by IR laser light. Good performance of the material for visualization of CO_2 laser beams has been demonstrated.

Thermal screen for visualization of far infrared laser radiation



Photographs of the $Y_{1-x}Mn_xAlO_3$ (x=0.0005) sample irradiated for a few seconds by 1 W Ar^+-laser (λ=514.5 nm) (a), and illuminated 2 W (b) power from CO_2 laser. Photo (b) was taken in the darkness

II. BOOKS AND BOOK CHAPTERS

1) S. Khizroev, R. Chomko, I. Dumer, D. Litvinov, "Multilevel and Three-dimensional Nanomagnetic Recording," Chapter 6, Nano-scale and Bio-inspired Integrated Computing, edited by Mary M. Eshaghian-Wilner, Wiley Publishers, 2008
2) F. Candocia and S. Khizroev, chapter in "Nanophysics, Nanoclusters and Nanodevices," *Nova Science Publishers,*2006, ISBN: 1-59454-852-8
3) S. Khizroev and D. Litvinov, *Perpendicular Magnetic Recording*, Kluwer Academic Publishers, 2005; ISBN 1-4020-2662-5 (Hard-cover Book) and 1-4020-2723-0 (e-book)
4) S. Khizroev, R. Chomko, and D. Litvinov, chapter "Nanoscale Magnetic Devices" in *Handbook of Semiconductor Nanostructures and Nanodevices*, edited by A.A. Balandin and K.L. Wang, American Scientific Publishers, 2005; ISBN 1-58883-073-X
5) D. Litvinov and S. Khizroev, chapter "Nanomaterials and Nanodevices Synthesized by Ion-beam Technology," *Dekker Encyclopedia in Nanoscience and Nanotechnology*, 2005; ISBN 0-8247-4797-6

III. GRADUATE STUDENTS INVOLVED

1) Nissim Amos, Ph.D.
2) Human Arjomandi, M.S., Summer 2006
3) Robert Cameron, M.S. Fall 2007, Hispanic
4) David Doria, M.S., Fall 2007, Hispanic ,currently engineer at Boeing Corporation
5) Nikhil Joshi, Ph.D.,
6) Esnick Felissaint, M.S., FIU, Spring 2007, African American
7) Patricia Ange Fievre, Ph.D. student, Female
8) Pablo Gomez, Ph.D., Summer 2006, FIU, Hispanic American, currently a PDF, UCR
9) Yazan Hijazi, Ph.D., Spring 2006, currently Assistant Professor, Puerto Rico
10) Rabee Ikkawi, Ph.D.
11) Derek Jacobs, Undergraduate Student, 2005-2006
12) Andrey Lavrenov, Ph.D., Spring 2007, currently a PDF, UCR
13) Kurt McKnabb, M.S., Summer 2006, FIU, African American, currently a Ph.D. student at FIU
14) Jose Martinez, PhD 2008
15) Abdullah Zackariya – M.S. Dec'07
16) Ange M. P. Fievre –M.S. Apr'06, Female currently a PhD student at FIU
17) Tao Liu , PhD student at FIU
18) Xuan Wang , PhD student at FIU
19) Raghunandan Seelaboyina, Ph.D., May 2007, Currently Postdoc position
20) Harindra N. Vedala, Ph.D. studentr, 2006, 2007,
21) Ved Prakash Verma, Ph.D .student , 2006, 2007
22) Srinivas Rao Boddepalli, M.S., 2006, Currently at BAE Systems
23) Feng Zheng, PhD student , 2006, 2007
24) Wenzhong Wu, PhD, graduated May 07

IV. INTERACTIONS WITH THE INDUSTRY

Via the active participation of Song Xue, Executive Director, Advanced Transducer Development, Seagate Technology, the research efforts have been extensively exposed to the industry. These industry related activities include:

1) Opportunities for summer internships for undergraduate and graduate students to Western Digital, Seagate, Motorola, Hitachi
2) Joint research projects with the industry: 1) Mutlilevel Magnetic Recording, with Michael Alex, Hitachi Global Storage Technologies, 2) Imprint-based Patterned Media, with Nikhil Joshi, Motorola, 3) 3D Magnetic Recording, with Song Xue, Exec. Director, Advanced Transducer Development, Seagate, 4) Patterned Soft Underlayers, with William Cain, VP, Western Digital, 5) Nanomagnetic Probes for Ultra-high Density Information Storage, with Bin Lu, Media Manager, Seagate Technology, and others
3) Several graduate students routinely spent a week at the Guzik facilities, San Jose, California, to obtain direct training to operate the Spinstand Guzik V2002 according to the tightest industry requirements to a recording system.
4) One patent has been filed (S. Khizroev, "Three-dimensional magnetic memory and/or recording device," US patent application 20060028766, filed February 9, 2006; 11/197,377, filed Aug 4, 2005, with provisional patent, 60/598,645, filed Aug 4, 2003, with FIU). Three companies, SanDisk, Seagate, and Simpletech, respectively, approached the PI's institution with the request to license the patent.
5) New-Span Opto Technology, Inc. - Co-developed Tunable Filter for 4x4 Wavelength Switch and provided addition support for the project at level of $30,000
6) Jose Martinez had a co-op experience at Texas Instruments, where he is now employed.
7) Ange M. P. Fievre had a co-op experience at Ball Semiconductors, and has been accepted for a co-op at GE.

V. PEER-REVIEW PUBLICATIONS

1) (invited) S. Khizroev, R. Ikkawi, N. Amos, R. Haddon, D. Litvinov, "Protein-based memory," *Materials Research Society (MRS) Bulletin* 33 (9), 21-8 (2008)
2) D. Litvinov, V. Parekh, C. E, D. Smith, J. Rantschler, P. Ruchhoeft, D. Weller, and S. Khizroev, "Nanoscale bit-patterned media for next-generation data storage systems," *J. Nanoelectronics and Optoelectronics* **3** (2), 93-112 (2008)
3) P. Gomez, D. Litvinov, and S. Khizroev, "A nanoscale nuclear magnetic resonance system for signature-based detection of biomolecules," *J. Nanoelectronics and Optoelectronics* **3** (2), 123-32 (2008)
4) D. Litvinov, V. Parekh, C. E, D. Smith, J. Rantschler, P. Ruchhoeft, D. Weller, and S. Khizroev, "Recording physics, design considerations, and fabrication of nanoscale bit-patterned media," *IEEE Trans. Nanotechnology* **7** (4), 463-76 (2008)
5) C. E, J. Rantschler, S. Zhang, S. Khizroev, T. R. Lee, D. Litvinov, "Low-temperature vacuum annealing study of $(Co/Pd)_n$ magnetic multilayers," *J. Appl. Phys.* **103**, 07B510 (2008)

6) D. Smith, V. Parekh, C. E, S. Z[redacted]g, W. Donner, T. R. Lee, S. Khizroev, D. Lit[redacted]v, "Magnetization reversal and magnetic anisotropy in patterned Co/Pd multilayer thin films," *J. Appl. Phys.* **103**, 023920 (2008)

7) (invited) D. Litvinov, V. Parekh, C. E, D. Smith, J. Rantschler, P. Ruchoeft, D. Weller, and S. Khizroev, "Nanoscale bit-patterned media for next generation data storage systems," special Spintronics issue of *J. Nanoelectronics and Optoelectronics* **4**, (2008)

8) S. Hernandez, E. Stefanescu, S. Khizroev, N. Myung, "Nanomagnetic sensors," *Electrochimica Acta* **53** (12), 24-28 (2008)

9) (invited) R. Ikkawi, A. Lavrenov, A. Krichevsky, D. Teweldebrhan, S. Ghosh, A. A. Balandin, D. Litvinov, and S. Khizroev, "Near-field optical transducer for heat-assisted magnetic recording for beyond 10-terabit/in^2 densities, *J. Nanoelectronics and Optoelectronics* **3**, 44-54 (2008)

10) N. Amos, R. Fernandez, R. Ikkawi, B. Lee, A. Lavrenov, A. Krichevsky, D. Litvinov, S. Khizroev, "Magnetic force microscopy study of magnetic stripe domains in sputter deposited Permalloy thin films, " *J. Appl. Phys.* **103** (7), 07E732 (2008)

11) V. Parekh, D. Smith, Chunsheng E, J. Rantschler, S. Khizroev, D. Litvinov, "He+ ion irradiation study of continuous and patterned Co/Pd multilyaers," *J. Appl. Phys.* **101**, 083904 (2007).

12) P. Gomez, D. Litvinov, and S. Khizroev, "A method to design high SNR nanoscale magnetic sensors using an array of tunneling magneto-resistive (TMR) devices," *Journal of Physics D: Applied Physics*, 40, 4396-404 (2007)

13) Chunsheng E, J. Rantschler, S. Zhang, D. Smith, V. Parekh, S. Khizroev, D. Litvinov, "Integranular interactions of low temperature atmosphere annealed Co/Pd magnetic multilayers," *J. Appl. Phys.* **101**, 09D108 (2007)

14) V. Renugopalakrishnan, S. Khizroev, H. Anand, L. Pingzuo, L. Lindvold, "Future memory storage technology: protein-based memory devices may facilitate surpassing Moore's Law," *IEEE Trans. Magn.* **43** (2), 773-5 (2007)

15) (invited) S. Khizroev, Y. Hijazi, N. Amos, E. Felissaint, N. Joshi, R. Ikkawi, R. Chomko, and D. Litvinov, "Physics of Perpendicular Recording with a Patterned Soft Underlayer," special information technologies issue, *J. Nanoscience and Nanotechnology* **7**, 243-54 (2007)

16) N. Amos, A. Lavrenov, P. Gomez, R. Chomko, F. Candocia, D. Litvinov, S. Khizroev, "Nanomagnetic probes to image patterned media for information densities above ten terabit-per-square-inch," *J. Nanoelectronics and Optoelectronics* **2**, 1-3 (2007)

17) D. Smith, Chunsheng E., S. Khizroev, D. Litvinov, "The influence of bit patterned medium design and imperfections on magnetoresistive playback," *IEEE Trans. Magn.* **42** (10), 2285-7 (2006)

18) Y. Hijazi, R. Ikkawi, N. Amos, A. Lavrenov, N. Joshi, D. Doria, R. Chomko, D. Litvinov, and S. Khizroev, "Patterned soft underlayers for perpendicular media," *IEEE Trans. Magn.* **42** (10), 2375-7 (2006)

19) Chunsheng E, D. Smith, E. Svedberg, S. Khizroev, D. Litvinov, "Combinatorial synthesis of Co/Pd magnetic multilayers," *J. Appl. Phys.* 99, 113901 (2006)

20) (invited) S. Khizroev, Y. Hijazi, N. Amos, D. Doria, A. Lavrenov, R. Chomko, T.-M. Lu, D. Litvinov, "Three-dimensional magnetic recording – an emerging nanoelectronic technology," *J. Nanoelectronics and Optoelectronics* **1**, 1-18 (2006)

21) D. Smith, Chunsheng E, S. Khizroev, D. Litvinov, "Magnetoresistive playback heads for bit-patterned medium recording applications," *J. Appl. Phys.* 99, 014503 (2006)

22) V. Parekh, Chunsheng E, D. Smith, A. Ruiz, P. Ruchoeft, E. Svedberg, S. Khizroev, D. Litvinov, "Fabrication of a high-anisotropy nanoscale patterned magnetic recording medium for data storage applications," *Nanotechnology* **17**, 2079 (2006)

23) S. Khizroev, Y. Hijazi, N. Amos, R. Chomko, and D. Litvinov, "Considerations in the design of three-dimensional and multi-level magnetic recording," *J. Appl. Phys.* **100**, 63907 (2006)

24) R.Seelaboyina and W Choi, "Recent Progress of Carbon Nanotube Field Emitters and Their Application", Recent Patents on Nanotechnology 3 238-244. (2007)

25) R. Seelaboyina, S. Boddepalli, K. Noh, M. Jeon and W. Choi, "Enhanced field emission from aligned multistage carbon nanotube emitter arrays", Nanotechnology 19 065605. (2008)

26) H. Vedala, S. Roy, M. Doud, K.Mathee, S. Hwang, M. Jeon and W. Choi, "Effect of Environmental Factors on Electrical Conductivity of Single Oligo-DNA Molecule Measured Using Single-walled Carbon Nanotube Nanoelectrodes", Nanotechnology, Nanotechnology 19, 26, 265704. (2008)

27) S.Roy, H.Vedala, A. Roy, D. Kim, M.Doud, K.Mathee, H. Shin, N.Shimamoto, V.Prasad and W. Choi, "Direct electrical measurements on single-molecule genomic DNA using single-walled carbon nanotubes", Nanoletters, 8(1), 26-30.(2007)

28) X. Wang, J. A. Martinez, M. S. Nawrocka and R.R. Panepucci," Compact Thermally Tunable Silicon Wavelength Switch: Modeling and Characterization", IEEE Photonics Technol. Lett Volume 20, Issue 11, June 1, 2008; pp:936 - 938

29) H.Y. Ng, M.R. Wang, D. Li, X. Wang, J. Martinez, R. R. Panepucci, K. Pathak, "1x4 Wavelength Reconfigurable Photonic Switch Using Thermally Tuned Microring Resonators Fabricated on Silicon Substrate", IEEE Photonics Technol. Lett. 19, pp:704-706 MAY 1, 2007

30) Han-Yong Ng; Michael R. Wang; Daqun Li; Xuan Wang; Jose A. Martinez; Roberto R. Panepucci; Kachesh M. Pathak, "4×4 wavelength-reconfigurable photonic switch based on thermally tuned silicon microring resonators", Optical Engineering 47(04), 044601, April 1, 2008; DOI:10.1117/1.2909662

31) J. Zakariya, T. Liu, and R. R. Panepucci, "Experimental demonstration of a wafer-level flexible probe for optical waveguide testing," *Opt. Express 15, pp: 16210-16215, Nov. 2007.*

32) Y Zhydachevskii, A. Durygin, V. Drozd , A. Suchocki , D. Sugak , J. Wrobel , "Structural and Spectroscopic Properties of Mn-doped YAlO3 Ceramics" Journal of Physics-Condensed Matter , 20, #095204,(2008)

VI. CONFERENCE AND WORKSHOP PRESENTATIONS

1) N. Amos, R. Ikkawi, A. Lavrenov, R. Chomko, S. Khizroev, "Multilevel magnetic recording devices," presented at 10th Joint MMM-Intermag, Baltimore, MD, January 7-11, 2007
2) R. Ikkawi, N. Amos, A. Lavrenov, R. Chomko, S. Khizroev, "Ferromagnetic resonance based memory devices," presented at 10th Joint MMM-Intermag,Baltimore, MD, January 7-11, 2007
3) (invited), S. Khizroev, A. Lavrenov, N. Amos, R. Chomko, D. Litvinov, "Focused ion beam as a nanofabrication tool for rapid prototyping of nanomagnetic devices," presented at Microscopy and Microanalysis 2006 Meeting, Chicago, IL, July 30 – August 3, 2006
4) S. Khizroev, "Three-dimensional Magnetic Memory," presented at US Air Force Office of Scientific Research (AFOSR) annual Nanoelectronics program review, Carnegie Mellon University, Pittsburgh, PA, August 7-9, 2006
5) (invited) D. Litvinov, V. Parekh, Chunsheng E, D. Smith, A. Ruiz, P. Ruchhoeft, J. Rantschler, and S. Khizroev, "Design and fabrication of high anisotropy nanoscale patterned magnetic recording medium for data storage applications," Meet. Abstr. – Electrochem. Soc. **602**, 1684 (2006).
6) V. Renugopalakrishnan, S. Khizroev, L. Lindvold, P. Li, H. Anand, "Protein-based memory," Nanoscience and Nanotechnology, 2006, ICONN'06, Intern. Conf. on NN, ISBN: 1-4244-0453-3
7) Y. Hijazi, N. Amos, A. Lavrenov, D. Doria, E. Felissaint, R. Chomko, D. Litvinov, S. Khizroev, presented at the IEEE Intermag Conference, San Diego, May 7-12, 2006
8) S. Khizroev, Y. Hijazi, N. Amos, D. Doria, A. Lavrenov, R. Ikkawi, R. Chomko, D. Litvinov, S. Khizroev, "Nanoscale information systems," 2006 Nanomaterials for Defense Applications Symposium, Virginia Beach, VA, May 1-4, 2006
9) R. Seelaboyina.,S.. Bodepalli, W K Jones and W Choi (2007), "Study of Electron Amplified Field Emission from Nanopowder Assisted Microchannel and Vertically Aligned Carbon Nanotubes", MRS-07 Fall Conference, Boston.
10) R. Seelaboyina, S .Bodepalli and W. Choi, "Robust and High Current Cold Electron Source Based on Carbon Nanotube",Field Emitters and Electron Multiplier Microchannel Plate, 137 TMS Annual Meeting. (2008)
11) R. Seelaboyina and W. Choi, "Field Emitters and Electron Microchannel Plate for High Current Applications", NanoMaterials for Defense Conference. (2008)
12) H. Vedala, S. Roy, M.Doud, K. Mathee and W. Choi "Influence of Environmental Factors on Electrical Conductivity of Single DNA Molecule using Single-walled Carbon Nanotube Electrodes." MRS Fall Conference, Boston. (2007)
13) Somenath Roy, Harindra Vedala and Wonbong Choi (November 2007) "Label-free Identification of Genomic DNA at the Single Molecule Level." MRS Fall Conference, Boston.
14) H. Vedala, S.. Roy, T..Kim, W.. Choi "Carbon Nanotube Interfaces for Single Molecular Level Bio Sensing", NSTI nanotechonlogy, Boston. (2008)
15) J. Huang, W. B. Choi "Controlled single-walled carbon nanotubes growth for high performance electronic devices", TMS 2008 New Orleans, LA.
16) T. Liu, and R. Panepucci,"Estimating Total Quality Factor of 2D Photonic Crystal Slab Cavities with 2D simulation Techniques"IPNRA- Integrated Photonics and Nanophotonics Research and Applications – Optics and Photonics Congress - IEEE/OSA, Boston, MA, July 14-17, 2008 Paper IWF7
17) T. Liu and R. Panepucci, "Fast Estimation of Total Quality Factor of Photonic Crystal Slab Cavities", UGIM 2008 – University Government Industry Microfabrication, Lousville, KY, July 14-17, 2008
    A. Zakariya, T. Liu, J.A. Martinez, and R. R. Panepucci, "Flexible Optical Probe for Planar Lightwave Circuit Testing"Conference on Lasers and Electro-Optics, CLEO 2008, Technical Digest, Paper JWA83, San Jose, CA, May 5-9, (2008);
18) R. R. Panepucci, A.J. Zakariya, T. Liu , "Flexible Optical Wire-bonding for Planar Lightwave Circuits Packaging", Nanoengineering: Fabrication, Properties, Optics, and Devices IV, edited by Elizabeth A. Dobisz, Louay A. Eldada, Proc. of SPIE Vol. 6645, 66450D1-66450D8, (2007) – San Diego, CA, August 2007
19) R. Panepucci, T.Liu, M.S. Nawrocka, „Polymers Photonic Crystal Cavities Fabricated by Direct Electron-Beam Lithography",The 50th Interational Conference on Electron, Ion and Photon Beam Technology & Nanofabrication, Baltimore, MD, May 31 - June 3, 2006
20) R.R. Panepucci, V.R. Almeida, X. Wang, A. Lavrenov, A. M. P. Fievre, "Sensing using nano-opto-electromechanical systems (NOEMS), International Microelectronics and Packaging Society (IMAPS) Emerging Technology Workshop on Nanotechnologies for Microelectronics, Las Vegas, NV, December 4-7, 2006.
21) V. R. Almeida and R.R. Panepucci, "Silicon Slot-Waveguide as NOEMS Photonic Platform", Frontiers in Optics 2006, Rochester, NY., October 8-12, 2006
22) V.R. Almeida and R. R. Panepucci, "NOEMS Devices Based on Slot-Waveguides", CLEO/QELS and PhAST 2007, Baltimore, MD, May 6–11, 2007
23) H. Ng, M. R. Wang, X. Wang, J. Martinez, R. R. Panepucci, D.Li , "8x8 Wavelength Reconfigurable Photonic Switch Using Thermally Tuned Micro-Ring Resonators Fabricated on Silicon Substrate" ,Frontiers in Optics 2006, Rochester, NY., October 8-12, 2006

A. M. P.Fièvre, T. Liu, R. Panepucci, "Nanotaper coupler for the horizontal slot-waveguide" Nanoengineering: Fabrication, Properties, Optics, and Devices IV, edited by Elizabeth A. Dobisz, Louay A. Eldada, Proc. of SPIE Vol. 6645, 66450E-1-66450E-8, (2007) – San Diego, CA, August 2007

24) M.R. Wang, H.Y. Ng, D. Li, X. Wang, J.Martinez, R. R. Panepucci, K.Pathak "Wavelength Reconfigurable Photonic Switching Using Thermally Tuned Micro-Ring Resonators Fabricated on Silicon Substrate", Nanoengineering: Fabrication, Properties, Optics, and Devices IV, edited by Elizabeth A. Dobisz, Louay A. Eldada, Proc. of SPIE Vol. 6645, 66450I-1-66450I-7, (2007) – San Diego, CA, August 2007

VII. PATENTS FILED

1. S. Khizroev, "Three-dimensional magnetic memory and/or recording device," US patent application 20060028766, filed February 9, 2006; 11/197,377, filed Aug 4, 2005, with provisional patent, 60/598,645, filed Aug 4, 2003, with FIU

---

[1] S. Khizroev, "Three-dimensional magnetic memory and/or recording device," US patent application 20060028766, filed February 9, 2006; 11/197,377, filed Aug 4, 2005, with provisional patent, 60/598,645, filed Aug 4, 2003, with FIU